Astrophysics Research And Analysis

Ultra-Low-Noise Sub-mm/Far-IR Detectors for Space-Based Telescopes

Completed Technology Project (2016 - 2021)

Project Introduction

The sub-mm and Far-IR spectrum is rich with information from a wide range of astrophysical sources, including exoplanet atmospheres and galaxies at the peak star formation. In the 10-400 μm range, the spectral lines of important chemical species such H2O, HD, and [OI] can be used to map the formation and evolution of planetary systems. Dust emission in this spectral range is also an important tool for characterizing the morphology of debris disks and interstellar magnetic fields. At larger scales, accessing the formation and distribution of luminous Far-IR and sub-mm galaxies is essential to understanding star formation triggers, as well as the last stages of reionization at z~6. Detector technology is essential to realizing the full science potential of a next-generation Far-IR space telescope (Far-IR Surveyor). The technology gap in large-format, low-noise and ultra-low-noise Far-IR direct detectors is specifically highlighted by NASA's Cosmic Origins Program, and prioritized for development now to enable a flagship mission such as the Far-IR Surveyor that will address the key Cosmic Origins science questions of the next two decades. The detector requirements for a mid-resolution spectrometer are as follows: (1) Highly sensitive detectors with performance approaching 10^-19 - 10^-20 WHz 1/2 for background- limited operation in telescopes with cold optics. (2) Detector time constant in the sub- millisecond range. (3) Scalable architecture to a kilo pixel array with uniform detector characteristics. (4) Compatibility with space operation in the presence of particle radiation. We propose phononic crystals to meet the requirements of ultra-low-noise thermal detectors. By design, a phononic crystal exhibits phonon bandgaps where heat transport is forbidden. The size and location of the bandgaps depend on the elastic properties of the dielectric and the geometry of the phononic unit cell. A wide-bandwidth low-pass thermal filter with a cut-off frequency of ~1.5 GHz and extending to 10 GHz can be realized with quasi-periodic phononic structures. A few 10^-19 WHz-1/2 detector sensitivity is readily accessible with phononic filter thermal isolation. Phononic filters are naturally compact, <20 μm in longest dimension, and contribute negligible heat capacity to a thermal sensor. We propose a three-year effort to fabricate and test phononic-isolated Transition- Edge Sensor arrays suitable for background-limited operation in a Far-IR Sur- veyor. We emphasize that phononic thermal isolation offers a viable path towards detector sensitivities an order of magnitude above that achieved with current state-of-the-art thermal detector technologies. Our effort addresses the APRA solicitation for advancing detector design and operation towards highly sensitive, compact, and robust characteristics.

Anticipated Benefits

The Astrophysics Research and Analysis program (APRA) supports suborbital and suborbital-class investigations, development of detectors and supporting technology, laboratory astrophysics, and limited ground based observing. Basic research proposals in these areas are solicited for investigations that are

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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Astrophysics Research and Analysis

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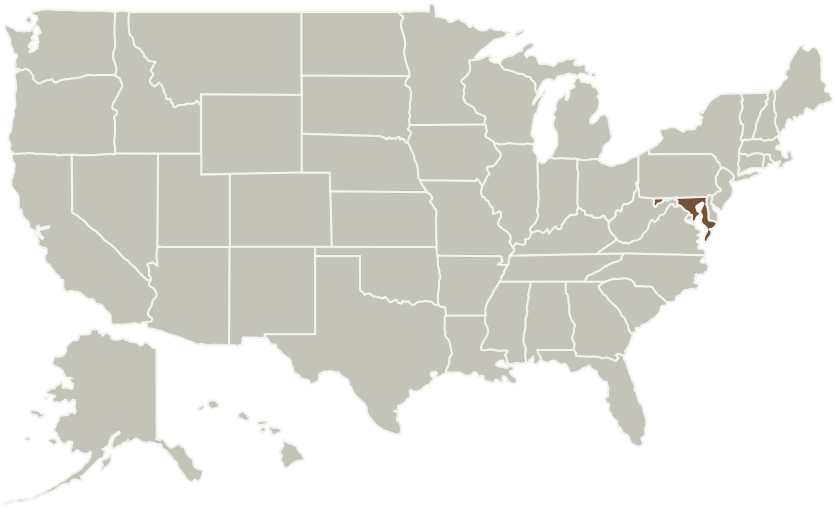
relevant to NASA's programs in astronomy and astrophysics, including the entire range of photons, gravitational waves, and particle astrophysics. The emphasis of this solicitation is on technologies and investigations that advance NASA astrophysics missions and goals.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Johns Hopkins University	Supporting Organization	Academia	Baltimore, Maryland

Primary U.S. Work Locations
Maryland

Project Management

Program Director:

Michael A Garcia

Program Manager:

Dominic J Benford

Principal Investigator:

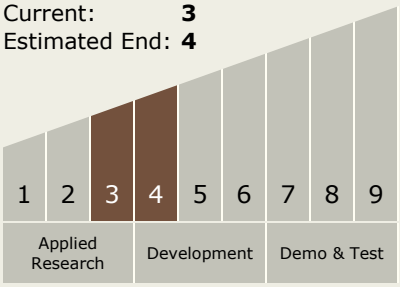
Karwan Rostem

Co-Investigators:

Kevin L Denis
Samuel H Moseley
Johannes G Staguhn
Edward J Wollack
Susanna S Ormond

Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **4**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - TX08.2 Observatories
    - TX08.2.3 Distributed Aperture

Target Destination

Outside the Solar System